Office of Naval Research International Field Office

Ocean, Atmosphere and Space Technology Newsletter 01-01

Atmospheric Turbulence Effects on Microwave Propagation - Research Activities - Airborne Research Australia and The Defence Science and Technology Organisation

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January 2001

These reports summarize global activities of S&T Associate Directors of the Office of Naval Research International Field Offices (ONRIFO). The complete listing of newsletters and reports are available under the authors' by-line on the ONRIFO homepage: http://www.ehis.navy.mil/ http://www.ehis.navy.mil/onrnews.htm or ONRIFO-Asia homepage: http://www.onr.navy.mil/onrasia/, or by email to respective authors.

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Keywords

Research Aircraft, Atmospheric Turbulence, Coastal Environmental Effects, Radio Frequency Refraction, Microwave Propagation, Refractivity modeling.

1. Summary

An ONRIFO visit to the Airborne Research Australia (ARA) facility at Parafield Airport, and the Defense Science and Technology Organisation (DSTO) Salisbury South Australia, revealed several opportunities for research collaboration in the domain of microwave propagation. ARA owns and operates a fleet of four highly specialized aircraft (Grob G520T Egrett, Beech B200T Super King Air, Cessna 404 Titan, Grob G109B), fully equipped to provide reliable and accurate physical and chemical atmospheric measurements (from a few meters above the ground to an altitude of 50,000 ft), as well as radiometry, remote sensing and many other aspects of airborne research. It is perhaps the only dedicated civilian facility of its kind in the Southern Hemisphere. DSTO utilizes these unique airborne assets to gain a better understanding of the effect of turbulence and refractive structures upon

Radio Frequency (RF) propagation, and in particular upon the performance of microwave ESM and radar surveillance systems. These research efforts will particularly assist studies of the operational effectiveness of navy and air force radar systems as a function of the environment. This newsletter is designed to inform US and international scientists, research and governmental institutions and international organizations about opportunities for potential collaboration.

2. Background

Airborne Research Australia 's Chief Scientist and Managing Director, Dr Jörg M. Hacker, hosted the ONRIFO visit and provided an overview and tour of the ARA Operations Base, located at Parafield Airport in Adelaide South Australia. ARA is Australia's National Research Aircraft Facility established through funding from the Commonwealth's Major National Research Facilities Program and Flinders University. ARA is a company fully owned by Flinders University. ARA's core business is the provision of airborne platforms (specialist airplanes) and services for a wide range of applications, mainly in the environmental Research & Development area. The ARA Operations Base has a multitude of onsite capabilities, including:

- Laboratory space with direct cable connections and data links to the aircraft;
- Basic facilities for mechanical and electronic work; and
- Calibration facilities.

The cost-effective integration of complex instrumentation in aircraft is one of the core capabilities of ARA, which also includes design, manufacture and certification of components and systems. Furthermore, it should be noted that ARA owns the only (civilian) high altitude sensor platform in the Southern Hemisphere, the Grob G520T Egrett (VH-ARA). The Grob G520T Egrett is a German-built former “Spy Plane” (first flown April 1993), the only existing high altitude aircraft, a two-seater, single propeller turbine engine aircraft capable of carrying a scientific payload of 750kg to altitudes of up to 15km (see below).

Parameter	Grob G520T
Useful Altitude range	6 - 15km
Typical endurance	8hrs
Typical range	2,500km
Typical scientific pay-load (excluding crew)	800kg
Approximate cabin dimensions available for instrumentation	not applicable
Special features	wing hardpoints; large instrumentation bays; pressurized
Flight procedures	VFR, IFR, in cloud, known icing
Engines	1 turbo-prop engine

This aircraft (and the other three) are made available for special applications of clients. For more information on ARA see http://ara.es.flinders.edu.au/

For DSTO, ARA is currently performing airborne measurements and data analysis of radar propagation in field trials within the atmospheric marine boundary layer over Gulf St Vincent in South Australia. Environmental characterization, particularly in the littorals is a focal area of high interest at ONRIFO. The S&T Liaison visit to ARA was followed up with visit to DSTO Salisbury.

DSTO has a central office in Canberra and two major laboratories, the Aeronautical and Maritime Research Laboratory in Melbourne and the Electronics and Surveillance Research Laboratory in Salisbury, outside Adelaide. Research facilities linked with these laboratories are located throughout Australia. DSTO is part of the Australian Department of Defence. For more information on DSTO see http://www.dsto.defence.gov.au/ .

At DSTO, Dr. John Hermann, Principal Research Scientist, Surveillance Systems Division, hosted the ONRIFO S&T Liaison Visit. Collaboration discussions focused on research efforts of the Surveillance System Division and the Electronic Warfare Division in the domain of Microwave propagation. The principal DSTO researchers involved in both the modeling and measurement activities are:

- Dr John Hermann (Principal Research Scientist, Surveillance Systems Division (SSD)); and
- Dr Andy Kulessa (Senior Research Scientist, Electronic Warfare Division (EWD)).

The below paragraphs highlights objectives, methodology, significant results, and collaboration desires of a group of research scientist from the Surveillance Systems Division and the Electronic Warfare Division to address several of the DSTO main R&D components in support of:

- RF signature measurement and electromagnetic modeling; measurement and modeling of radar scattering for in-service Australian Defence Force (ADF) platforms and systems, and for future ADF acquisitions;
- Environmental Analysis and Propagation: Ionospheric effects on HF signal propagation and on Global Positioning System (GPS) operation; microwave radar propagation; radar clutter and imagery backgrounds; and
- Surveillance, reconnaissance and targeting: Enhancing situational awareness through detection, identification and location of signals propagating in free space, such as those from enemy radars

3. Research Objectives of Surveillance Systems Division (SSD) and Electronic Warfare Division (EWD)

The immediate objectives of the SSD/EWD research activity include:

- contributions to a data base facilitating in particular the modeling of atmospheric structures affecting the performance of EW and microwave radar systems;
- investigation of methods for measuring local atmospheric profiles as an essential prerequisite to assessing sensor effectiveness;
- development of understanding of the impact of signal fluctuations upon microwave sensor performance; and
- assessment of the extent and manner in which microwave radar systems and EW systems will be compromised by atmospheric refractive effects.

As an output from these objectives, DSTO SSD/EWD also expect to gain an enhanced understanding of how boundary layer turbulent processes affect the formation of anomalous refractive structures.

4. Methodology

DSTO is studying refractivity variations in the boundary layer and the approach has been to make direct measurements of mean profiles in the marine surface layer and the littoral boundary layer. Fluctuations associated with atmospheric turbulence within the surface layer have also been measured and plans are to extend these measurements to higher elevations. DSTO is interested in modeling the connections between the spatial aspects of large-scale refractive structures and parameters measuring turbulence strength. The experimental program involves the simultaneous measurement of extended turbulence and refractivity profiles, making use of and comparing direct aircraft measurements, with measurements from instrumented buoys. Work being carried out this year will also make use of radar measurement techniques, and radiosonde techniques, including quite possibly dropsonde techniques at a later stage.

5. Research Activities

DSTO modeling capability includes refractivity models developed for evaporation ducts and for non-standard refractive index variations within the boundary layer caused by mesoscale atmospheric processes. Monte-Carlo techniques have been used to model microwave propagation through a stochastically varying surface layer. DSTO has a particular interest in the micrometeorology of ducts and in surface layer theory.

Previous DSTO studies of the evaporation duct include the collection of evaporation duct statistics, refractivity profile modeling, and the role of micrometeorology and atmospheric processes including turbulence.

Project Refractive Turbulence - aimed at gathering turbulence profiles and related data in the lower and upper regions of the atmosphere, and in utilizing this data to facilitate investigations and modeling of turbulence and refractive structures upon EO, IR and RF propagation and upon the performance of surveillance and EW systems**.** In another part of this project, measurements have been made in and around the Jetstream over Southern Australia and Japan using special purpose-built turbulence probes fitted to ARA's Egrett high altitude aircraft. This part of the study was funded by the AFOSR and AOARD.

Project arrangement PA16 – utilizes measurements made with NOAA aircraft, to investigate atmospheric parameters including those in the vicinity of cloud tops where large humidity gradients and refractive gradients can be expected.

One of the aims of these experiments is to ascertain the spatial extent, thickness, strength and prevalence of ducts occurring at these altitudes. These ducts presumably will have a significant impact upon, for example, AEW surveillance and ESM systems.

The propagation simulations involve the use of hybrid models comprising the parabolic equation method (PEM) and ray tracing. The impact of turbulence upon ducting and radio holes is of considerable interest, and DSTO is currently carrying out a parameter study. They are interested in using Monte Carlo methods and higher-moment methods to simulate the effects of atmospheric turbulence.

Other specific modeling carried out at DSTO to date includes, studies of the impact of lower level tropospheric ducts and radio holes upon the operation of medium-power microwave transmitters, and the effects of elevated ducts upon high-powered transmitters located at greater altitudes. Activity of relevance to dropsonde deployment for assessing atmospheric profiles is being carried out

Recent research results to date are:
(a) Development of a model linking atmospheric turbulence to properties of the evaporation duct;
(b) Modeling of signal parameters within a stochastic atmosphere;
(c) Development of techniques for modeling meteorological profiles within the littoral region; and
Investigation of dropsonde dynamics and deployment in different wind conditions.

6. Unique Measurement Assets

The atmospheric physics group at Adelaide University and Airborne Research Australia (ARA) are working cooperatively with DSTO under contract. The unique measurement features at DSTO's disposal include a VHF boundary layer radar profiler to study horizontal and vertical structure of irregularities (54 MHz, 1 microsec pulse length, spaced antenna mode), facilities for extensive wind profiling, direct measurement of refractive-turbulence (C_n^2) profiles, aircraft measurements of standard meteorological variables, and

sampling techniques and strategies.

ARA owns one of only two instruments worldwide for the airborne measurement of sea surface salinity. The SLFMR (Scanning Low Frequency Microwave Radiometer) works in the 1.4GHz band and coupled with an array of IR-SST sensors is flown on ARA's Cessna 404 aircraft.

7. Assessment

DSTO SSD/EWD in conjunction with ARA are dedicated to measuring all aspects of atmospheric parameters, analyzing data, and providing accurate models that predict RF propagating in various environments, including the littorals. Their programs complement the propagation work carried out in this area at SPARWARSYSCEN in San Diego CA and in other national labs across the U.S. S&T community. The airborne assets and equipment at ARA, make it a unique facility, flexible, and responsive to the research needs of any client, at affordable costs. The regional expertise of DSTO SSD/EWD provides a variety of collaboration opportunities in projects focusing on the climatology of ducting under various coastal environments. Specifically, they would like to relate and apply DSTO's electromagnetic modeling techniques to realistic scenarios, involving measurements of atmospheric profiles in both temperate and tropical environments. Other areas of potential research collaboration are in model verification studies. These research efforts will assist studies of the operational effectiveness of navy and air force ESM and radar systems as a function of the environment.

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